

Appendix 3.3

Water Quality and Aquatic Habitat Issue Analysis Report

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Issue Statement: Certain portions of the existing road system generate sediment that impacts water quality and aquatic habitat. Such impacts are more detrimental when they occur in watersheds that provide habitat for Threatened, Endangered, or Sensitive anadromous fish species.

1. Findings –

We organized the findings into two categories. The first category deals with aquatic resources that are subject to road impacts on the Mendocino NF. The second category deals with the sources of potential impacts to those aquatic resources.

1.1. Aquatic Resources Subject to Road Impacts

- The primary beneficial uses of water on the Mendocino include anadromous and resident fisheries, other aquatic and riparian species, and reservoir storage.
- We rated the relative value of aquatic resources of the 5th field watersheds based on the presence of fish habitat.
 - Presence of anadromous habitat warranted a high rating, as several of our existing or historic anadromous stocks are federally listed as Threatened or Endangered. Impacts to these species carries greater risk of irreparable harm.
 - Presence of a substantial resident trout fishery warranted a medium rating, as trout are sensitive to sediment impacts
 - Watersheds without either of the above aquatic resources were rated low, as they are least sensitive to the known potential impact sources.
- Reservoir storage is less sensitive to impacts than are the fish and other aquatic and riparian species. Therefore, the presence or absence of reservoirs within or downstream of a 5th field watershed did not affect its aquatic resource rating.
- The relative values of aquatic resources of the 5th field watersheds are displayed in Table A3.3 – 6.

1.2. Sources of Potential Impacts

1.2.1. Poaching

- Poachers are known to use roads and trails to reach the Middle Fork of the Eel and the Black Butte River to take Threatened steelhead.

1.2.2. Migration Barriers

- Fish migration barriers are not considered to be a significant problem on the Mendocino.
- Twenty road/stream crossings were found to be barriers to resident fish.
- There are no known road crossing barriers to anadromous fish.
- Table A3.3 -7 displays information regarding the location and nature of fish migration barriers, including the urgency of correcting each situation.

1.2.3. Sediment Production

1.2.3.1 Magnitude and Context

- Roads probably contribute about 3% to 7% of the average annual sediment production from both natural and human causes. This includes both surface erosion and mass wasting sources.
- Sediment from roads and other human causes does not appear to be in excess of the sediment transport capabilities of the stream systems on the Forest.
- Road system does not affect municipal or community water systems.
- Road sediment probably does result in localized impairment of aquatic habitat in the form of turbidity and siltation in some areas.

1.2.3.2. Location of Potential Impacts

GIS analysis identified locations of highest indicators of potential road sediment impacts. Road-specific locations were determined for key routes only, using GIS analysis and available road-specific condition information. Watershed-specific locations were determined using GIS analysis of both key and non-key routes, but included no road-specific condition information.

Key Routes

- The 375 miles of key routes on the Forest are predominantly ML3 or ML4, which have wider road prisms than most other Forest roads. This tends to increase the potential magnitude of impacts resulting from design or location problems as compared to other roads.
- There are about 15 miles (4%) of key routes located on unstable lands¹.
- There are about 99 miles (26%) of key routes located within 150 feet of streams².
- Key routes cross 1096 streams, which equates to an average of 2.9 crossings per mile. This is within 16% of the forest-wide average of 2.5 crossings per mile.
- One key route (M-1) is located on two floodplains (Soda Creek and Gravelly Valley). There are chronic problems with sediment deposition at two stream crossings in Gravelly Valley, due to a combination of faulty bridge design and alteration of the local base level by Lake Pillsbury.

¹ Active landslides and inner gorges.

² Includes order 1 intermittent streams.

- No key routes are located on wetlands.
- Key routes were rated for potential sediment impacts in Table A3.3 –25. Detailed information upon which the ratings are based is displayed in Table A3.3- 26.

Fifth Field Watersheds

- Of the three key watersheds on the Forest, Upper Middle Fork Eel River have the lowest rating in road indicators expressing potential man-induced sediment from roads. Thatcher/Williams watershed was rated moderate from impacts whereas the Black Butte River was rated the highest.
- 5th field watersheds are rated for potential road related sediment impacts in Table A3.3 –18. The ratings are comparisons of the *indicators* of sediment *potential* of the watersheds relative to each other. We could not determine at this scale, with the available data, the *actual* sediment *impacts*. That task will have to be done in the watershed/project scale analysis, supported by the collection of road-specific inventory data.
- Table A3.3 –19 displays the indicators of sediment potential of 7th field watersheds, which is useful information for focusing analysis and improvement work at the watershed/project scale.

1.2.3.3. Influence of Design, Use, and Climate -

We analysed the general influence of several road characteristics on sediment delivery to the stream system from road related surface erosion. The characteristics we analysed were: design style, wet weather use, road width, and climate zone. The first three characteristics were important because they have a strong influence on sedimentation rates and can be changed by management. The influence of climate zone was analysed because similar management changes result in greater sediment reductions in one zone than in the other. Knowledge of the nature and magnitude the influences of these characteristics is important in prioritizing sediment reduction efforts.

A brief explanation of the terms we use to describe these four characteristics necessary before discussing our findings.

- Design Style – Two road design styles were analysed, referred to as ‘old’ and ‘new’. Old style roads are predominantly of a confined drainage design, characterized by an insloped running surface, inboard ditches and outboard berms. New style roads are predominantly of an unconfined drainage design, characterized by an outsloped running surface, and with minimal inboard ditches and outboard berms.
- Wet Weather (Wx) Use – Two road-use regimes were analysed: unrestricted and restricted. Under the restricted use regime, traffic is restricted when road surfaces are wet and vulnerable to rutting. The unrestricted use regime results in more severe rutting, which in turn increases the sediment rate.
- Road Width – We analysed two nominal road widths, 15 and 25 feet, to represent typical dimensions of maintenance level 2 and maintenance level

3 roads, respectively. These are referred to as ML2 and ML3 in the text and tables.

- Climate Zone – Two zones were analysed: a rain + snow zone (500 to 5000 feet elevation) and a snow zone (over 5000 feet elevation).

We analysed the influence of various combinations of these characteristics. For brevity, distinct combinations of characteristics are referred to generically as 'Typicals'. The results are summarized in Tables A3.3 –1, A3.3 –2, A3.3 -3, below.

Table A3.3 -1 - Comparison of Estimated Sediment Rates Among Typicals					
Design Style	Wet Wx Use	Avg Sediment Delivery³ (tons/mi/yr)			
		Rain + Snow Zone		Snow Zone	
		ML2	ML3	ML2	ML3
Old	Unrestricted	108	166	51	89
	Restricted	94	146	40	75
New	Unrestricted	95	158	48	85
	Restricted	51	119	18	56
New + Gravel	Unrestricted		62		11
Recently Closed		47		13	

³ Tonnage figures are most valuable for comparison purposes. They are averages for 'typical' characteristics of each road design type and wet weather use regime. The actual magnitudes of the rates are accurate to only +/- 50% (Eliot, et al, 1999), so their use for estimating actual sediment production is limited. In comparison to the estimated average sediment rate of 49 tons per mile from the Eel & Mad River Basin sediment study (USDA 1970), these estimates appear to be somewhat high, but within the stated accuracy range.

Table A3.3 -2 - Effects of ML2 Management Changes on Sediment Rates										
Zone	Current Management		Reduced Sediment per Management Change							
	Design Style	Wet Wx Use	Restrict Use		Convert to New Style		Convert to New + Restrict		Close ⁴	
			Tons	%	Tons	%	Tons	%	Tons	%
Rain + Snow	Old	Unrestricted	14	13%	13	12%	57	53%	61	56%
		Restricted					43	46%	47	50%
	New	Unrestricted	44	46%					48	51%
		Restricted							4	8%
Snow	Old	Unrestricted	11	22%	3	6%	33	65%	38	75%
		Restricted					22	55%	27	68%
	New	Unrestricted	30	63%					35	73%
		Restricted							5	28%

Table A3.3 -3 - Effects of ML3 Management Changes on Sediment Rates										
Zone	Current Management		Reduced Sediment per Management Change							
	Design Style	Wet Wx Use	Restrict Use		Convert to New Style		Convert to New + Restrict		Convert to New + Gravel	
			Tons	%	Tons	%	Tons	%	Tons	%
Rain + Snow	Old	Unrestricted	20	12%	8	5%	47	28%	104	63%
		Restricted					27	18%	84	58%
	New	Unrestricted	39	25%					96	61%
		Restricted							57	48%
Snow	Old	Unrestricted	14	16%	4	4%	33	37%	78	88%
		Restricted					19	25%	64	85%
	New	Unrestricted	29	34%					74	87%
		Restricted							45	80%

⁴ This assumes new design style, freshly graded prior to closure, and no revegetation or mulching of the running surface. This is the initial rate immediately after closing; the rate would decrease gradually as natural revegetation occurs on the running surface in the absence of traffic.

We can draw the following conclusions from this information:

General

- Road mileage is a crude and not very useful measure of sediment impacts. Relying solely on reducing road mileage is a poor strategy for reducing impacts to aquatic resources.
- A variety of manageable factors, in addition to road mileage, influence sediment impacts.
- A variety of management actions, in addition to road closure, are available to reduce sediment impacts while meeting other environmental and socio-economic needs.

Influence of Design Type and Wet Weather Use

- Old style roads with unrestricted wet weather use have the highest sediment rates.
- Restricting wet weather use on old style roads reduces sediment rates as much or more than reconstructing to the new style without restricting use.
- Restricting wet weather use on new style roads that are currently unrestricted can substantially reduce sediment rates further.
- Current Equivalent Roaded Acre methodology for quantifying cumulative watershed effects does not account for these differences in assessing the variable contribution of roads to cumulative effects.

Influence of Climate Zone

- Roads of similar design and use regime produce substantially more sediment (about double) in the rain + snow zone than in the snow zone. Conversely, similar changes in design and /or use regime can be expected to achieve substantially greater sediment reductions in the rain + snow zone than in the snow zone.
- According to information in Table A3.3 – 17, about 75% of the road system is in the rain + snow zone.
- The previous two points indicate that the greatest opportunity for sediment reduction is in the rain + snow zone.

1.3. Need for Forest Plan Amendment

Existing management direction under standards and guides for Facilities & Transportation, Soils & Geology, and Watershed & Water Quality provide adequate direction to manage the road system to protect water quality and aquatic habitat. The analysis did identify opportunities and guidance (refer to Guidelines section) to focus and improve implementation of Forest Plan management direction.

2. Guidelines

The following suggestions are intended to assist road managers to effectively implement road-related Forest Plan management direction.

2.1. Need for Forest Plan Amendment – None.

2.2. Identifying Opportunities and Setting Priorities

- Tables A3.3 –6 and A3.3 –18 provide aquatic resource and sediment rankings of the 5th field watersheds for consideration when prioritizing watershed/project-scale road analysis or improvement work. Table A3.3 – 19 provides additional information regarding sediment potential of 7th field watersheds that is useful for prioritizing work within 5th field watersheds.
- When prioritizing watershed/project scale roads analysis and inventory efforts, assigning higher priority to 5th field watersheds that have higher ranking in both the 'Aquatic Resource' and 'Sediment' categories will assure that situations that have the greatest potential need for improvement are assessed and improved first (order of ranking would be H&H > H&M > M&M > M&L > L&L).
- Pending completion of watershed-scale roads analysis, the same ranking scheme can be used to help prioritize potential sediment reduction projects.
- Within high priority 5th field watersheds, aquatic habitat will benefit most by prioritizing sediment reduction projects according to the cost per unit of sediment reduction, the sediment rating of the 7th field watershed, and proximity to impacted aquatic habitat. Plates 9 –13 in Appendix 5 show the proximity of high and medium ranked 7th field watersheds to aquatic resources for selected 5th field watersheds. Tables A3.3 –4 and A3.3 -5 provide a general sense of the relative cost effectiveness of various types of projects.
- Since key routes have a larger road prism and have higher funding priority than other Forest roads, focus on segments of key routes that are located 7th field watersheds that have high sediment ratings as a starting point.
- Consideration of cost per unit of sediment reduction in prioritizing multi-purpose road improvement projects will optimize their effectiveness in reducing overall road impacts.
- Submit the sediment findings of this analysis for consideration during the development of the TMDL implementation plan for the Upper Middle Fork Eel watershed. Follow the TMDL implementation plan when developed.
- Prioritize correction of fish passage barriers according to Table A3.3 –6.

Table A3.3 -4 - Cost per Ton of Sediment Reduction for Selected Management Changes on ML2 Roads										
Zone	Current Management		Unit Cost & Reduced Sediment per Management Change							
	Design Style	Wet Wx Use	Restrict Use		Convert to New Style		Convert to New + Restrict		Close	
			Tons	\$/T	Tons	\$/T	Tons	\$/T	Tons	\$/T
Rain + Snow	Old	Unrestricted	14	\$58	13	\$885	57	\$216	61	\$202
		Restricted					43	\$267	47	\$245
	New	Unrestricted	44	\$19					48	\$17
		Restricted							4	\$0
Snow	Old	Unrestricted	11	\$74	3	\$3833	33	\$373	38	\$324
		Restricted					22	\$523	27	\$426
	New	Unrestricted	30	\$50					35	\$43
		Restricted							5	\$0

Table A3.3 -5 - Cost per Ton of Sediment Reduction for Selected Management Changes on ML3 Roads										
Zone	Current Management		Unit Cost & Reduced Sediment per Management Change							
	Design Style	Wet Wx Use	Restrict Use		Convert to New Style		Convert to New + Restrict		Convert to New + Gravel	
			Tons	\$/T	Tons	\$/T	Tons	\$/T	Tons	\$/T
Rain + Snow	Old	Unrestricted	20	\$60	8	\$2,400	47	\$434	104	\$1638
		Restricted					27	\$711	84	\$2014
	New	Unrestricted	39	\$31					96	\$1575
		Restricted							57	\$2632
Snow	Old	Unrestricted	14	\$86	4	\$4,800	33	\$618	78	\$2185
		Restricted					19	\$1,011	64	\$2644
	New	Unrestricted	29	\$41					74	\$2043
		Restricted							45	\$3333

2.3. Watershed and Project Scale Analysis

- Applicable Forest Plan standards and guides: Facilities & Transportation # 6, 9, 15.
- Table A3.3 –26 lists the questions from the Roads Analysis Book (USDA Forest Service 1999) that need to be addressed at the watershed/project scale. The following points provide some insight into how to address some of the questions (the numbers of applicable questions appear in [brackets]). For some of the questions, forest-scale analysis produced no insights that would assist lower scale analysis.
- [AQ-1, 2, 4, 6] At the watershed/project scale, collection and use of road-specific inventory data is needed to estimate road-specific surface erosion sediment rates with WEPP:Road (or other suitable model). These values are needed to:
 - validate or correct the indicator-based rating of 7th field watersheds that was developed in the forest-scale analysis.
 - prioritize road sediment reduction opportunities.
 - compare the relative changes in sediment production between road management alternatives.
 - adjust Equivalent Roaded Acre coefficients of roads in the Mendocino NF cumulative watershed effects database.
- Other survey/inventory needs include:
 - [AQ- 3] Existing and potential mass movement into streams - document sites and prioritize for improvement.
 - [AQ- 1] Identify stream diversion potential at culverts.
- [AQ- 7, 12, 14] Document the aquatic resource values (beneficial uses) that are most sensitive to road-related impacts, and their location in relation to verified impact sources. Use this information to prioritize impact reduction efforts. Use information in Table A3.3 –6 as a starting point.
- [AQ10] Fish migration barriers are well documented (Table A3.3 –7); watershed/project analysis should evaluate if/where migration of other aquatic species are affected.

2.4. Construction

- Applicable Forest Plan standards and guides: Facilities & Transportation # 5, 7, 8, 9, 11, 15; Soils & Geology # 2, 5; Watershed & Water Quality # 1c, 1d, 2a.
- Use WEPP:Road (or other suitable model) and site specific data to assess the efficacy of various design options in minimizing new sediment production.
- Avoid constructing new roads in 7th field subwatersheds that have verified high sediment impacts (as determined by watershed/project-scale analysis).

2.5. Reconstruction and Deferred Maintenance

- Applicable Forest Plan standards and guides: Facilities & Transportation # 5, 6, 7, 8, 9, 15.
- When performing deferred maintenance, seize opportunities to reduce hydrologic connectivity and sediment delivery by minimizing width, out-sloping, removing berms, decreasing the distance between drainage dips and between ditch relief culverts, and improving bank stability near stream crossings.
- Continue to upgrade culverts to pass 100-year floods, especially in priority watersheds.

2.6. Operation and Maintenance

- Applicable Forest Plan standards and guides: Facilities & Transportation # 5, 10, 13, 15; Watershed & Water Quality # 1d.
- The existing standards established by the Forest Supervisor in the decision document Road Repair and Maintenance, CY1998 – 2002 are appropriate means of minimizing road-related sediment production. Continued adherence to these standards is supported by our findings.
- Consider the following when reviewing and updating the standards for road repair and maintenance:
 - Use Forest specification 812 for snow removal operations.
 - Delay spring snow removal and allow roads to melt out naturally.
 - Install panel markers at cross drains on roads frequently plowed for snow.
 - Utilize water in road grading operations when soil is too dry to properly compact, if the added expense does not compromise the achievement of acceptable surface drainage function system-wide.
 - Develop wet season road use guidelines that are consistent Forest wide.

2.7. Closure & Decommissioning

- Applicable Forest Plan standards and guides: Facilities & Transportation #4, 6; Watershed & Water Quality # 1d, 2b.
- Consider cost per unit of sediment reduction, and risk of catastrophic failure when choosing between closure, minimal decommissioning, and full obliteration.

3. Analysis

3.1. Values Subject to Road Impacts

Table A3.3 -6 displays the beneficial uses and relative importance/sensitivity of aquatic values among the 5th field watersheds. The species most subject to irreparable harm are the several anadromous fish stocks that are federally listed as Threatened or Endangered, or designated as Forest Service Sensitive species. The watersheds that provide habitat for these species were given the highest value rating. Watersheds were given a medium value rating if they had no anadromous habitat within the Mendocino NF but which have substantial resident trout habitat or anadromous fish downstream. Other watersheds were rated low.

Table A3.3 -6 – Ranking of Aquatic Resource Values of 5th Field Watersheds		
Watershed Name	Issue Description and Miles of Habitat	Score
Bear Creek	• Resident trout	M
Black Butte River	• Anadromous fish 31 miles; • Resident trout 15 miles	H
Briscoe Creek	• Resident trout 15 miles	M
Coyote Creek	•	L
Elder Creek	• Resident trout 8 miles; down-stream anadromous	M
Elk Creek	• Anadromous fish 8 miles Resident trout 5 miles	H
Grindstone Creek	• Resident trout 43 miles	M
Lakeport	•	L
Little Stony Creek	• Resident trout 9 miles	M
Lucern	•	L
Middle Fk Stony Cr	• Resident trout 44 miles	M
North Fk Cache Creek	• Resident trout 24 miles	M
North Fk Eel River	• Anadromous fish and resident trout (downstream of Forest)	M
North Fk Stony Cr	•	L
Red Bank Creek	• Anadromous fish (downstream of Forest)	M
Rice Fork	• Resident trout 52 miles	M

Table A3.3 -6 – Ranking of Aquatic Resource Values of 5th Field Watersheds		
Watershed Name	Issue Description and Miles of Habitat	Score
S Fk Cottonwood Cr	<ul style="list-style-type: none"> • Anadromous fish 5 miles • Resident trout 3 miles 	H
Soda Creek	<ul style="list-style-type: none"> • Resident trout 4 miles • Anadromous 17 miles 	H
Thomes Creek	<ul style="list-style-type: none"> • Anadromous fish downstream of Forest • Resident trout 51 miles 	M
Tomki Creek	<ul style="list-style-type: none"> • Anadromous fish 3 miles 	H
Upper Lake	<ul style="list-style-type: none"> • Resident trout 6 miles 	M
Upper Main Eel River	<ul style="list-style-type: none"> • Resident trout 102 miles 	M
Upper Middle Fork Eel	<ul style="list-style-type: none"> • Anadromous fish 28 miles • Resident trout 48 miles 	H
Williams-Thatcher	<ul style="list-style-type: none"> • Anadromous fish 3 miles • Resident trout 2 miles 	H

3.2. Sources of Potential Impacts

There are three categories of potential risk. Two of them, poaching and migration barriers, are fairly localized. The other category, sediment, occurs forest-wide to varying degrees.

3.2.1. Poaching

Evidence of poaching has been discovered in the Middle Fork Eel River and Black Butte River in several areas by the California Department of Fish and Game biologists and wardens. Adult summer steelhead are the primary targets in the Middle Fork Eel, while both adult and juvenile winter steelhead are taken in the Black Butte. The poachers generally use the remnants of old 'jeep' roads to get closer to the river. The most accessible have been closed and this closure needs to be monitored for effectiveness. The poaching seems concentrated during the deer season when more people are in the area, but there have been some instances in which it was associated with marijuana cultivation.

3.2.2. Migration Barriers

When a road crosses a stream, accommodation for the water must be made. The simplest crossing is called a "low water crossing" when the stream bottom becomes part of the road. Such crossings are frequently hardened with a concrete slab that the water runs over. Low water crossings are frequently too

deep for vehicles in the high flows period. Large and important crossings often are bridged. On the Mendocino National Forest the vast majority of crossings are made with the use of round culverts. Culverts must pass water expected in an estimated 100-year storm. Efforts to pass that much water frequently run in opposition to aquatic life passage. USDA-Forest Service (1980) prepared a practical guide to assessing and solving fish passage problems. In 2002 Region 5 of the Forest Service along with collaborators developed further fish passage assessment refinements.

A low water crossing can be a barrier and some are on the Mendocino NF. Bridges can be barriers in some situations, but on the Mendocino NF, none are barriers. Most culverts on the Forest are potential barriers to fish and to other aquatic life such as frogs. However, for various reasons not all are important barriers.

The surveys and observations of culverts on the Mendocino over the past 27 years have found 20 culverts that prevent adult fish passage. All of those barriers are on resident streams only. The anadromous crossings are either bridges or low water crossings that allow for adult passage. Table A3.3 –7 displays information regarding the location, nature, and degree of impact from existing barriers.

Shading indicates the degree of urgency of correcting the barrier: medium gray = high; light gray = medium; none = low.

Table A3.3 -7 – Resident Fish Migration Barriers	
Road Number/ Stream Name/ Watershed Name	Correction Needed⁵
18N01/ Letts / MF Stony	Corrective action not needed at this time. Stream gradient is steep with natural barriers to upstream migration.
18N03/ NF Stony / MF Stony	Corrective action not needed at this time. Concrete ford that acts as a barrier to warm-water species. This barrier is considered beneficial for cold-water species.
22N01/ Grindstone / Grindstone	Removal desirable but is a low priority. A steel deck bridge has failed and catches gravels.
23N02/ Grindstone / Grindstone	Corrective action is desirable but a low priority since there is less than ¼ mile of upstream habitat. Trout are found upstream of the pipe.

⁵ Corrective action could involve replacing culvert with a bridge, an open arch culvert, or modifying existing culvert with baffles.

Table A3.3 -7 – Resident Fish Migration Barriers	
Road Number/ Stream Name/ Watershed Name	Correction Needed⁵
24N01/ Thomes / Thomes	Correction desirable for resident fish but does not appear feasible. The existing concrete ford is the only type of improved crossing possible due to the sharp turn, narrow gorge, unstable banks, and very high seasonal flows. Since there is a thriving trout population above “The Slab” correction is not imperative.
M-1 / Hammerhorn / Middle Fork Eel	Correction not cost effective. There is a 5-foot waterfall 1/8 mile upstream. Rainbow trout are found above culvert now.
M-21 / Smoke-house / Middle Fork Eel	Correction not cost effective. This is a very large culvert; 12’ diameter and 166 feet long with cement inlet and downstream apron. There is about ¼ mile of habitat upstream. This structure could be replaced with an open arch eventually. Corrective action is low priority.
M-1 / Bar / Middle Fork Eel	Correction not necessary. The stream gradient is very steep and there are trout upstream.
M-1 / Fly / Middle Fork Eel	Correction not necessary. The stream gradient is very steep and there are trout upstream.
22N10 / Plaskett / Black Butte	Correction not necessary at this time. The stream gradient is very steep and there are trout upstream. If culvert were replaced, an open arch culvert would be desirable. Corrective action is low priority.
M-6 / Upper Main Eel (or Sand Creek) / Upper Main Eel	This crossing has two twelve foot pipes with a 4- foot drop from the pipes to the downstream plunge pool. There is a thriving resident trout population above and below the culvert and natural barriers within a short distance upstream. Because of the sheer size of the culverts and the barriers as well as presence of trout upstream, there is no immediate need to replace these culverts with a bridge or open arch culverts
M-6/ Trout/ Upper Main Eel	Corrective action is desirable and a high priority.
M-6/ Horse/ Upper Main Eel	Corrective action is desirable and a high priority.
18N04/ Thistle Glade/ Upper Main Eel	Correction not necessary at this time. The stream gradient is very steep and there are trout upstream. If culvert were replaced, an open arch culvert would be desirable. Corrective action is low priority.
18N04/ Copper Butte/ Upper Main Eel	Correction not necessary at this time. The stream gradient is very steep and there are trout upstream. If culvert were replaced, an open arch culvert would be desirable. Corrective action is low priority.

Table A3.3 -7 – Resident Fish Migration Barriers	
Road Number/ Stream Name/ Watershed Name	Correction Needed⁵
18N04/ Skeleton / Upper Main Eel	Correction is desirable. If culvert were replaced, an open arch culvert would be desirable. Corrective action is medium priority.
18N04/ Deer / Upper Main Eel	Correction not necessary at this time since there are trout upstream. If culvert were to be replaced, an open arch culvert would be desirable. Corrective action is medium priority.
20N08/ Corbin /Upper Main Eel	Correction not necessary at this time. If culvert were replaced, an open arch culvert would be desirable. Corrective action is medium priority.
20N08/ Dutch Oven /Upper Main Eel	Correction not necessary at this time. If culvert were replaced, an open arch culvert would be desirable Corrective action is medium priority
20N08/ Five Springs /Upper Main Eel	Correction not necessary at this time. If culvert were replaced, an open arch culvert would be desirable Corrective action is medium priority

Information for Table A3.3 -7 comes from the 1974 Forest-wide “Operation Swimup” survey, a 2001 contract survey, and inspection of all these sites by a fishery biologist. The guidelines for Operation Swimup were subjective and allowed the surveyors to make a judgment as to whether the culverts or low water crossings were barriers. The fish passage contract involved careful measurements that were entered into a software program. The fish passage results of the 2001 survey confirmed earlier Operation Swimup findings.

3.2.2. Sedimentation

3.2.2.1. Magnitude and Context

The best available information that is specific to road-related sediment production on the Mendocino NF is a 1970 study of sediment sources of the Eel and Mad River basins (USDA, 1970). The study estimated sediment production from various sources, including roads. Table A3.3 -8 displays data for studied watersheds that occur on the Mendocino NF.

Table A3.3 -8 - Estimated Overall & Road-Related Sediment Production Major 5th Field Watersheds of Eel River Basin w/in MNF (ca 1970)			
Watershed	Average Annual Sediment Production		
	All Sources ⁶ (Acre Feet)	Roads	
		Acre Feet ⁷	% of Total
Upper Main Eel & Rice Fork	388	12	3.1%
Upper MF Eel	442	15	3.5%
Black Butte	313	11	3.5%
Wms/Thatcher	135	5	3.6%
Elk Creek	467	14	3.0%

The report projected a potential doubling of this rate over the subsequent 50 year period (1970 – 2020). This was based on assuming a doubling of the road mileage and no improvement in road management practices. The report did not provide 1970 road mileage figures, so we have no ability to test that part of the assumption with respect to the Mendocino NF. However, the Forest Service has incorporated most of the recommended practices into its road management since the 1970's. Consequently, erosion rates per mile of road are probably lower than in 1970. Probably the best estimate of the current road portion of total sediment production would be somewhere between 3% and 7%, based upon a larger road system that is managed for lower per-unit sediment production.

Watershed analysis efforts have documented a continuing trend in the improvement of stream conditions on the Mendocino NF since the 1964 flood event (USDA Forest Service 1994, 1995a&b, 1996a&b, 1997a&b, 1999, 2000a). This indicates that road and other human caused sediment, when added to natural sources, is not in excess of the transport capability or other hydrologic functions of the stream system.

Nevertheless, the sediment contribution from roads cannot be discounted. Sediments from roads tends to be fine (silt and sand), and numerous studies have related that increased levels of fine sediment have deleterious effect on fish and their prey base (Cordone and Kelley 1961). Areas of excessive road-related sediment production that occur in 5th field watersheds with high aquatic resource values (Table A3.3 –6) are the most likely to result in significant impacts to

⁶ Includes both natural and human caused sediment sources in several categories: stream bank erosion, landslides, roads (surface erosion only), sheet and gully erosion (includes temporary roads and several other natural and human caused sub-categories). The stream bank erosion and landslide categories included some road-induced sediment production (the basin-wide average was about 2.8% of their combined production).

⁷ This value was computed by adding the following estimated rates together: 100% of the road surface erosion category; 100% of the temporary road sub-category of the sheet and gully erosion category; and 2.8% of the combined stream bank erosion and landslide categories.

Threatened or Endangered fish. For this reason, such areas should receive priority for efforts to reduce road-related sediment.

The 1970 report recommended 14 management practices aimed at reducing road-related sediment production. As noted in A3.3 –9, all of these recommendations are embodied in road related Forest Plan management direction or water quality Best Management Practices (USDA Forest Service. 2000).

Table A3.3 -9 - Crosswalk of Recommendations to Existing Management Direction		
Recommendation	Existing Management Direction	
	Forest Plan	BMPs
1. Soil and geologic conditions should be investigated so that road locations can be planned to avoid steep slopes and areas of unstable soil and rock. In potential problem areas, excavation and soil disturbance should be reduced even though the best alignment may sometimes be sacrificed.	Soils & Geology #2	2.1
2. Roads should be constructed during the dry season.		2.3
3. Large fills and waste accumulations should not be allowed near channels. Where possible, cut slopes should be no steeper than 1.5 to 1, and fill slopes no steeper than 2 to 1. All cut and fill slopes that will support vegetation should be protected from erosion by seeding grasses, planting shrubs or trees, and applying mulch and fertilizer.	Facilities & Transportation #5	2.4, 2.5
4. Excess material should be end-hauled to selected disposal sites away from streams, where it can be protected against erosion.		2.10
5. All fills should be compacted during construction.		2.5, 2.10
6. When it is absolutely necessary to construct roads in unstable soil and landslide areas, special surface and subsurface drainage should be provided.		2.6
7. Roads should be located so that fills will not encroach upon streams during peak flows. Riprap and retaining walls should be provided to protect fills when it is necessary to locate them within high-water elevations at culvert or bridge crossings.		2.10, 2.13
8. Fording of live streams with construction equipment should be avoided.		2.13, 2.14

Table A3.3 -9 - Crosswalk of Recommendations to Existing Management Direction		
Recommendation	Existing Management Direction	
	Forest Plan	BMPs
9. The location of stream crossing points should be selected to minimize the disturbance to stream banks and streamflow. Bridges or culverts should be provided at all watercourses for both temporary and permanent roads. Bridge piers and abutments should be aligned to minimize deflection of current. Culverts should be designed to permit the free movement of fish.	Facilities & Transportation #7	2.1
10. Adequate surface drainage facilities should be installed. Down-drains and energy dissipators should be installed at outlets of drainage ditches and culverts to prevent outflow water from being discharged directly onto unprotected slopes. Whenever possible, culvert outlets should be located in existing waterways or in rocky areas. In erodible channels, energy dissipators should be provided at culvert outlets. Surfaced dips or outsloping should be considered for lower-standard roads to prevent accumulation [concentration] of drainage flows.	Facilities & Transportation #8	2.7
11. All roads that will be used during the wet months should be surfaced.	Facilities & Transportation #10	2.24
12. All drainage ditches, pipe, and culverts should be inspected each year and repaired or cleaned out prior to the rainy season. Maintenance operations should not remove the toe of cutbanks, and the excess material should not be deposited on stream banks.	Facilities & Transportation #10, 13	2.22
13. Cut and fill areas should be inspected periodically for possible maintenance needs.		2.22

3.2.2.2. Location of Potential Impacts

Key Routes

Key routes were rated based upon the presence of sediment indicators and whether the road is located in a high sediment potential 5th field watershed. Key route ratings and supporting information are displayed in Table A3.3 –25. Because these ratings are based only on indicators of *potential* sediment problems, they may not reflect actual conditions. The priority ratings are useful for prioritizing inventory and assessment on key routes, which in turn helps to identify and prioritize actual improvement needs.

5th Field Watersheds

Questions from the Road Analysis handbook related to water quality and aquatic habitat were addressed by using several road/water interaction indicators. The following discusses indicators used for the analysis.

The potential for road-related sedimentation impacts within 5th field watersheds was evaluated using the following indicators: road density, road/stream⁸ crossings, proximity to streams, and unstable slopes. GIS analysis was used to determine the magnitude of each indicator for each 7th field watershed, and then the 5th field watersheds were rated based on the proportion of their 7th field watersheds that had high sediment potential. The reason for this approach is that 5th field watersheds are fairly large, and include relatively large areas with few or no road/water interaction indicators. Such areas tend to obscure the presence of areas with concentrations of indicators when a large watershed is assessed as a whole.

By evaluating the smaller 7th field watersheds, we could identify concentrations of road sediment indicators within the 5th field watersheds. This allows us to get past the obscuring problem, and also provides some spatial sense as to where road impacts are most likely to occur within the 5th field watersheds and in relation to the location of important aquatic habitat.

We translated the magnitude of each indicator for each 7th field watershed into a rating of high (3), medium (2), or low (1), as explained below. This was necessary in order to compensate for the disparate units of measure for the various indicators. We then summed those ratings to determine the summary rating for each 7th field watershed. Table A3.3 –19 displays the results of this process.

It is important to note that this was strictly a ‘dry lab’ exercise. The ratings are based entirely on indicators, not on inventoried conditions. Further, we stratified the values for three of the four indicators into a high-medium-low ranking by equal percentile groups. The ranking of indicators in this way is suitable only for establishing the relative standings of the watersheds regarding their *potential* for impacts.

This is appropriate at this scale of analysis, but the ratings must be validated (or corrected) by field investigation and inventory of actual road and stream conditions during watershed/project scale roads analysis. In many cases, potential impacts have been avoided or mitigated by incorporating special design features. In other cases, improper design or maintenance may result in a problem where there normally should be none.

Further, we were not able to include privately managed roads in our GIS analyses. For this reason, indicators for 7th field watersheds with significant inclusion of private land have probably been underestimated.

⁸ Includes intermittent streams.

The following discusses why each indicator was chosen, and how it was evaluated. Recall that the indicators were evaluated at the 7th field watershed scale.

Road Density

The density of roads (miles of road per square mile of watershed) in a watershed is one indicator of how roads may influence sediment delivery, streamflow and channel stability. It is a rough measure of the proportion of the watershed that has had its surface hydrology altered by roads through compaction, accelerated runoff, diversion, and increased erosion.

Density's shortcoming as an indicator is that it does not measure the proximity of the road system to streams or unstable lands. As noted below, the proximity of roads to these landscape features strongly influences the potential for impacts to occur. Density also fails to account for the effects of road width on the acreage of roads within a watershed⁹.

To define areas of road concentration, road density was calculated for all roads within each watershed. Road density was calculated by dividing the miles of road in the watershed by the size of watershed in square miles. The watersheds were then rated high (3), medium (2), or low (1) as follows:

- High – density greater than 3.0 miles per square mile. This is based upon a threshold of concern suggested by National Marine Fisheries Service in recent Level 1 consultations (Divide Auger Timber Sale).
- Medium – density between 1.5 and 3.0 miles per square mile.
- Low – density less than 1.5 miles per square mile

The break between medium and low was set at ½ of the threshold of concern for lack of information to suggest some other break-point.

Road/Stream Crossings

Impacts to streams may occur when a road crosses a channel. Nearly all of the road/stream crossings on the Forest utilize a culvert. Culverts impact stream stability by increasing water velocity through the pipe. The increased velocity can cause downstream bank erosion and channel bottom scour. Most of these effects are localized near the culvert, and tend to stabilize within a few years of culvert installations (assuming proper installation).

Also, if a culvert plugs with debris, water may build up behind the road fill creating a small impoundment. Depending on the intensity and duration of the storm and degree of blockage, impounded water may eventually pass through the culvert. Or it may run over the fill causing rills, gullies or fill erosion. Or the water may be diverted down the road creating gullies in the roadbed or on the slope if diverted across the road prism. Although the latter two scenarios occur

⁹ A mile of ML3, average width of 25 feet would measure about 3 acres (25 ft x 5280 ft / 43560 sq ft), whereas a mile of ML2 road would only measure about 1.8 acres (15 ft x 5280 ft / 43560 sq ft), only 60% as much as ML3.

infrequently, very large volumes of sediment can be eroded into stream channels in such cases.

Thus, the amount of stream crossings can be an indicator of potential for periodic, large sediment deliveries. Although stream crossings are also an indicator of hydrologic connectivity, the better indicator for that is proximity-to-streams, the next indicator discussed.

The road/stream crossings were delineated by overlaying the GIS road layer with the stream layer. Intersection of the two lines represents a crossing. The indicator was quantified in terms of the number of stream crossings per square mile in a watershed. This was calculated by dividing the number of crossings in the watershed by the size of watershed in square miles. The watersheds were then rated high (3), medium (2), or low (1) as follows:

- High – upper 1/3 of values.
- Medium – middle 1/3 of values.
- Low – lower 1/3 of values.

We rated the values by breaking them into three equal percentile groups for lack of information to suggest some other break-point.

Proximity to Streams

Proximity to streams is an indicator of hydrologic connectivity. Roads near streams have greater potential to impact water quality and peak flows. Road water and sediment have a short distance to travel through the streamside zone to the stream channel. The effectiveness of the streamside zone in keeping road runoff water and sediment from reaching the channel depends on distance from the road to the stream, road drainage features (outslope, cross drains), soil type and streamside zone steepness and ground cover.

Nearly all the roads on the Forest are located on uplands as opposed to being located on flatlands subject to flooding. For this reason, there is not much potential for impairment of floodplain function.

This indicator was measured in terms of miles of road within 150 feet of a stream. The 150-foot distance was chosen, because this is the default width for perennial non-fish bearing stream riparian reserves, as established in the Forest Plan. In most cases this is of sufficient width for vegetation and organic ground cover to slow and filter sediment from unconcentrated road runoff.

The indicator was quantified in units of miles of road per square mile of watershed. This was calculated by dividing the number of miles of road in the watershed that are within 150 feet of a stream by the size of watershed in square miles. The watersheds were then rated high (3), medium (2), or low (1) as follows:

- High – upper 1/3 of values.
- Medium – middle 1/3 of values.
- Low – lower 1/3 of values.

We rated the values by breaking them into three equal percentile groups for lack of information to suggest some other break-point.

Unstable Slopes

Unstable land features includes active landslides and inner gorge. Roads crossing these features have increased risk of causing landslides. Such slides can generate large amounts of sediment to enter the stream system. Slope steepness, bedrock geology and geomorphology were not used as indicators since these features are less direct indicators of potential instability than are active landslides and inner gorges.

This indicator was measured in terms of miles of road on unstable land. The indicator was quantified in units of miles of road in the watershed that are located on unstable slopes. The watersheds were then rated high (3), medium (2), or low (1) as follows:

- High – upper 1/3 of values.
- Medium – middle 1/3 of values.
- Low – lower 1/3 of values.

We rated the values by breaking them into three equal percentile groups for lack of information to suggest some other break-point.

Summary Ratings of 7th Field Watersheds

The next step was to add up the individual indicator ratings for each watershed to compute its summary rating. We then ranked the watersheds as high, medium, and low based upon equal percentile groups. Table A3.3 -19 displays the individual indicator ratings and the summary rating for each 7th field watershed. Watersheds that were ranked high (top 1/3 of the summary ratings) have the greatest potential for having road impacts to aquatic resources.

Ranking the 5th Field Watersheds

Having ranked the 7th field watersheds, we proceeded to use that information to rank the 5th field watersheds. We evaluated the 7th field information in two ways to develop the 5th field rankings.

The first was to rank them according to the proportion of their overall area that is occupied by high-ranked 7th field watersheds. This was calculated by adding up the areas of the high-ranked 7th field watersheds and dividing by the area of the 5th field watershed within the Mendocino NF boundary¹⁰. We then ranked the 5th field watersheds as follows:

- High – above average proportion of high-ranked 7th field watersheds.
- Medium – below average proportion of high-ranked 7th field watersheds.
- Low – no high-ranked 7th field watersheds.

¹⁰ GIS and INFRA data limited our analysis of indicators to within the MNF boundary, so we did not want to dilute the rankings for 5th field watersheds that have significant acreage outside of the boundary.

This measure gives a good sense for which 5th field watersheds have an above-average amount of high-ranked 7th field watersheds, but does not account for potential cumulative effects of having a large number of medium-ranked 7th field watersheds.

To get at this, we developed a cumulative sediment rating by normalizing and summing the 7th field summary ratings for each 5th field watershed. The 7th field summary ratings were normalized by multiplying each by its 7th field watershed's area and dividing by the 5th field watershed's area. Then these values were summed to get the weighted score. We then ranked the 5th field watersheds by breaking them into three equal percentile groups.

Our overall ranking was based on both of these rankings, as follows:

- High – either ranking was high.
- Medium – neither ranking was high, and at least one ranking was medium.
- Low – both rankings were low.

Table A3.3 -18 displays the rankings of the 5th field watersheds

3.2.2.3. Influence of Design, Use, and Climate

In order to prioritize sediment reduction efforts, managers need a sense of which types of roads are the worst offenders, and of the relative effectiveness of various management actions in reducing sediment delivery. It would also be helpful to have some indication of which areas of the Mendocino have the greatest potential road sediment delivery. To provide this information, we developed a sediment model for the Mendocino NF road system.

At the forest scale we do not have all the data needed to do a detailed sediment analysis based upon road-specific conditions. However, we do have enough geospatial data that we can combine with road manager knowledge of general road conditions to conduct a useful generalized sediment analysis. Using these information sources, we characterized the road system in terms that could be used to provide input to a road sediment model (WEPP:Road).

Characterization of the Road System

To facilitate modeling, we divided the road system into 16 typical combinations of two road sizes (ML2 & ML3), two design styles (old & new), two wet weather use regimes (restricted & unrestricted), and two climate regimes ('snow' & 'rain + snow'). We also modeled the effects of closing an ML2 and graveling of an ML3. For each of these typical combinations (hereinafter referred to as 'typicals'), we used geospatial analysis and road manager estimates to develop the WEPP:Road parameter input values (see discussions below for details).

As noted above, each typical is represented by a composite of several unique sets of WEPP:Road parameters. So the sediment rate for each typical is derived from the weighted average of the results of several runs of the WEPP:Road interface, and as a function of each typical's connectivity values.

A typical's connectivity values were based upon the relationship between the average road segment length and the GIS derived, forest-wide average number

of stream crossings per mile. The percent connectivity is directly related to the probability that an average road segment will be intersected by a stream. The general formula is:

$$\% \text{ Connected} = \text{Avg road segment length} / \text{Avg stream spacing}^{11}$$

Each typical's connectivity value was a weighted composite of the values for each gradient class. Refer to the "Apportionment of WEPP:Road Outputs to MNF Typical" discussion for details.

Development of WEPP:Road Input Parameters

WEPP:Road is an adaptation of a water erosion model for use in predicting delivery of sediment from roads to streams (Eliot, et. al. 1999). We utilized the user interface provided on the web (<http://forest.moscowfs.wsu.edu/fswepp>) to calculate estimated sediment delivery rates. The interface requires the input of several parameters, which it uses to predict erosion and sediment delivery rates. The development of the values for each of the input parameters is discussed below.

- Climate – The forest was divided into two climate zones: snow zone, and rain + snow zone. These were represented, respectively, by the Manzanita Lake and Nevada City climate settings. The snow zone is above 5000 feet elevation and the rain + snow zone is below.
- Soil Type – We used the 'clay loam' soil type.
- Design Type – As noted earlier, we lumped roads into two basic design styles: the 'old' style with predominantly confined drainage, and the 'new' style with predominantly unconfined drainage. Each style includes both insloped and outsloped segments, but in different proportions. Table A3.3 –10 displays the relationship between our design 'styles' and the WEPP:Road design 'types'.

¹¹ Average stream spacing for the Mendocino NF was calculated using GIS data. There are 6,878 stream crossings on 2,751 miles of road, so average spacing is $2,751 / 6,878 = 0.4$ mile, or 2112 feet.

Table A3.3 -10 –MNF Design Styles vs WEPP:Road Design Types				
Mtc Level	MNF Design Style	WEPP:Road Design Type		
		Insloped, Bare Ditch	Insloped, Vegetated Ditch	Outsloped, Rutted
2	Old	52.5%	22.5%	25%
	New	17.5%	7.5%	75%
3	Old	52.5%	22.5%	25%
	New	35%	15%	50%

We estimated that about 70% of insloped roads had bare ditches, and 30% had sufficient vegetation or rock to be fairly represented by the ‘insloped, vegetated ditch’ design type.

We used the ‘outsloped, rutted’ design type to model outsloped segments in all cases except for the ‘Recently Closed’ typical, as recommended in the WEPP:Road documentation. We modeled the difference in degree of rutting between restricted and unrestricted wet weather use by altering the road segment length (see the Road Specifications discussion of the length parameter).

To model the closed (but not decommissioned) ML 2 road, we used the ‘outsloped, unrutted’ design type to model the outsloped portion of a new style road. To model a graveled ML 3 road, we used the ‘insloped, vegetated ditch’ design type to model all of the insloped portion, and used the ‘graveled’ surface type option.

- Surface Type – We used the ‘native’ surface type for all runs except for the graveled ML 3 typical.
- Road Dimensions –The interface requires input of three road dimension values: grade (%), segment length (ft), and width (ft). Table A3.3 -11 displays the values used for input to the WEPP:Road program.

Table A3.3 -11 – Road Dimension Values						
Mtc Level	Design Type	Width (ft)	Road Segment Length (ft) by Grade Class			
			4%	6%	8%	10%
2	Insloped, bare ditch	17	500	500	350	300
	Insloped, vegetated ditch	17	500	500	350	300
	Outsloped, unrutted	15	100	135	170	200
	Outsloped, rutted (light)	12	100	135	170	200
	Outsloped, rutted (heavy)	12	500	500	350	300
3	Insloped, bare ditch	27	500	500	350	
	Insloped, vegetated ditch	27	500	500	350	
	Outsloped, rutted (light)	19	175	225	280	
	Outsloped, rutted (heavy)	19	500	500	350	

The sources of the values in Table A3.3 -11 are discussed below.

- **Grade** –The sediment production for each typical was modeled as the weighted average of the predicted sediment production for each of four grade classes. Table A3.3 -12 displays our estimates of the percent of ML 2 and ML 3 roads that are within four road grade classes.

Table A3.3 -12 - Percent of Road per Grade Class				
Mtc Level	4% Grade	6% Grade	8% Grade	10% Grade
2	40%	40%	10%	10%
3	45%	45%	10%	<1%

- **Length** – The road segment lengths listed in Table A3.3 -11 were set to the estimated average cross-drain spacing for insloped design types and for outsloped/rutted design types with heavy rutting (from unrestricted wet weather use).

The segment lengths for outsloped, rutted design type with light rutting (wet weather use restricted) were estimated to be about 5 times the effective length of the unrutted flow path as calculated in the WEPP:Road documentation. These calculated figures seem to roughly approximate what we have experienced in the field, and are displayed in Table A3.3 -13.

Table A3.3 -13 – Segment Lengths				
Mtc Level	Gradient	Effective Slope¹²	Effective Length¹³	Rutted Length
2	4%	5.7%	21.2	106.1
	6%	7.2%	27.0	135.2
	8%	8.9%	33.5	167.7
	10%	10.8%	40.4	201.9
3	4%	5.7%	35.4	176.8
	6%	7.2%	45.1	225.3
	8%	8.9%	55.9	279.5

- Width – Table A3.3 -14 displays the road width values, based upon the following assumptions and WEPP:Road protocols:
- ☐ Nominal width of ML2 = 15 feet; ML3 = 25 feet.
 - ☐ Insloped roads have a ditch that is added to the nominal width.
 - ☐ The outboard shoulder between the road edge and outboard rut is deducted from the nominal width of outsloped/rutted roads. This was estimated to be about 3 feet for ML2, and 6 feet for ML3 (most traffic occurs further from the road edge on wider roads).
 - ☐ Outsloped/unrutted roads have no additions or deductions from the nominal width.

Table A3.3 -14 – Road Width Input Values					
Mtc Level	Design Type	Widths in Feet			
		Nominal	Ditch	Shoulder	WEPP Input
2	Insloped	15	2	NA	17
	Outsloped, Rutted	15	NA	3	12
	Outsloped, Unrutted	15	NA	NA	15
3	Insloped	25	2	NA	27
	Outsloped, Rutted	25	NA	6	19
	Outsloped, Unrutted	25	NA	NA	25

¹² Effective slope is the slope produced by the combination of the road's grade and cross-slope.

¹³ Effective length is the length of a diagonal line across the road and parallel to the direction of the effective slope. It is the path runoff would take from the uppermost corner of a road segment to the point it leaves the road, if the road segment were a perfectly smooth plane.

- Fill Specifications – No data was available to estimate average values for these parameters.
 - Gradient – Set to the default value of 50%
 - Length – Set to the nominal road width.
- Buffer Specifications
 - Gradient – This value was set to 30% for all runs, based on WEPP:Road analysis of GIS data. We analysed the effect of buffer slope on sediment delivery by holding all input variables constant and running the program for 10% buffer slope increments. GIS analysis determined the proportion of the road system within each 10% buffer slope class through 70%. The weighted average sediment delivery was calculated by multiplying the unweighted sediment production of each slope class by the proportion of the road system within that class. The weighted average turned out to be fairly approximated by the unweighted sediment delivery for 30% buffer slope. Table A3.3 -15 displays the calculation of the weighted average.

Table A3.3 -15 – Effect of Buffer Slope on Sediment Delivery			
Slope Class	Unweighted Delivery (T/Mi)	% of Road System	Weighted Delivery (T/Mi)
0-10%	6.1	10.5	0.6
10-20%	15.6	23.6	3.7
20-30%	24.6	34.0	8.6
30-40%	36.2	23.4	8.5
40-50%	43.9	6.9	3.1
50-60%	47.1	1.3	0.6
60-70%	50.0	0.3	0.1
Weighted Average Delivery:			25.0

- Length – This was set to 300 ft for all runs to represent the delivery rate for unconnected road segments. This figure was used as a constant value rather than as an estimated average value. No effort was made to estimate a median or weighted average value.

In all, 76 distinct parameter sets were run through the WEPP:Road program (see Table A3.3 –20 for a sample WEPP:Road Output Log table). For each parameter set, the program calculated two sediment values. The first value (Sed Road) is the amount of road prism erosion, which estimates the amount of sediment delivered by road segments that are hydrologically connected to the stream system. The second value (Sed Profile) estimates the amount of sediment that is delivered from road segments from which runoff is filtered by a vegetated buffer before entering a stream channel.

Apportionment of WEPP:Road Outputs to MNF Typical

Once the sediment delivery values were generated by the WEPP:Road program, they needed to be apportioned to the MNF typicals. Apportionment was based upon each typical's unique combination of grades, connectivity, and design types. The first step was to calculate the weighted sediment rates for each typical by multiplying the sediment rate for each WEPP:Road design type by the percent of the typical that it represented (% values from Table A3.3 -10). The results of these calculations are displayed in Tables A3.3 -21a, 22a, 23a, 24a.

The next step was to aggregate these values into the 'connected' and 'unconnected' sediment rates, also displayed in Tables A3.3 -21a, 22a, 23a, 24a. The connected rate is the sum of the values in the 'Sed Road' columns; the unconnected rate is the sum of the values in the 'Sed Profile' columns.

The third step was to calculate and sum the weighted sediment rates for the hydrologically connected and unconnected portions of each typical. This is calculated by the formula:

$$[(\text{connected sed rate}) \times (\% \text{ connected})] + [(\text{unconnected sed rate}) \times (\% \text{ unconnected})],$$

and displayed in Tables A3.3 -21b, 22b, 23b, 24b in the 'Weighted Average' column.

Finally, the weighted average rates, which are in units of pounds per lineal foot, are converted to tons per gradient class by multiplying by the number of feet in each gradient class, and dividing by 2000 (Tables A3.3 -21b, 22b, 23b, 24b, 'Sediment Delivered' column). The sum of the gradient classes gives the sediment rate for the typical in tons per mile (the number in bold in the 'Sediment Delivered' column). Table A3.3 -16 compiles these figures to facilitate comparison.

Table A3.3 -16 - Comparison of Estimated Sediment Rates Among Typical					
Design Style	Wet Wx Use	Avg Sediment Delivery (tons/mi/yr)			
		Rain + Snow Zone		Snow Zone	
		ML2	ML3	ML2	ML3
Old	Unrestricted	108	166	51	89
	Restricted	94	146	40	75
New	Unrestricted	95	158	48	85
	Restricted	51	119	18	56
New + Gravel	Unrestricted		62		11
Recently Closed		47		13	

Distribution of Roads Within the Climate Zones

As can be seen from Table A3.3 -16, there is a substantial difference between the sediment rates of similar typicals located in different climate zones. This prompted us to check the distribution of the Mendocino's road system within the two zones. We used GIS analysis to determine the miles of road within each zone by 5th field watershed. We also calculated an index value, which compares the percent of roads in each watershed that are within the rain + snow zone to the forest-wide percentage. Values greater than 1.0 indicate a higher than average proportion of roads within the rain + snow zone. Results are displayed in Table A3.3 -17.

Table A3.3 -17 - Distribution of the Road System by 5th Field Watershed and Climate Zone					
Watershed	Rain + Snow Zone >5000'		Snow Zone >5000'		Index
	miles	Pct.	miles	Pct.	
Bear Creek	3.6	100.0%	0.0	0.0%	1.3
Black Butte River	174.0	52.8%	155.3	47.2%	0.7
Briscoe Creek	134.4	87.9%	18.4	12.1%	1.2
Coyote Valley	1.5	100.0%	0.0	0.0%	1.3
Elder Creek	44.8	51.9%	41.5	48.1%	0.7
Elk Creek	47.1	75.8%	15.0	24.2%	1.0
Grindstone Creek	227.2	73.2%	83.1	26.8%	1.0
Lakeport	0.2	100.0%	0.0	0.0%	1.3
Little Stony Creek	66.3	97.5%	1.7	2.5%	1.3
Lucerne	8.0	100.0%	0.0	0.0%	1.3
Middle Fork Stony Creek	146.9	90.5%	15.3	9.5%	1.2
North Fork Cache Creek	131.6	100.0%	0.0	0.0%	1.3
North Fork Stony Creek	26.3	100.0%	0.0	0.0%	1.3
Red Bank	4.0	88.9%	0.5	11.1%	1.2
Rice Fork	141.7	98.9%	1.6	1.1%	1.3
Soda Creek	96.6	100.0%	0.0	0.0%	1.3
S Fork Cottonwood Creek	4.8	39.1%	7.4	60.9%	0.5
Thomes Creek	248.3	61.1%	157.9	38.9%	0.8
Tomki Creek	12.3	79.4%	3.2	20.6%	1.1
Upper Lake	84.3	100.0%	0.0	0.0%	1.3
Upper Main Eel River	286.6	70.5%	120.0	29.5%	0.9
Upper Middle Fk Eel River	130.4	72.9%	48.4	27.1%	1.0

Table A3.3 -17 - Distribution of the Road System by 5th Field Watershed and Climate Zone					
Watershed	Rain + Snow Zone >5000'		Snow Zone >5000'		Index
	miles	Pct.	miles	Pct.	
Williams-Thatcher Creek	32.7	56.8%	24.9	43.2%	0.8
Totals	2053.7	74.7%	694.4	25.3%	1.0